Placement of Satellites

Teacher Demonstration

Time:

30 minutes

Objectives:

Students will develop an understanding that gravitational forces between the Sun and other Solar System bodies determines the point of placement for man-made satellites.

Content Standards:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
  - Identify questions and concepts that guide scientific investigations
  - Formulate and revise scientific explanations and models using logic and evidence
  - Recognize and analyze alternative explanations and models

Equipment, Materials, and Tools:

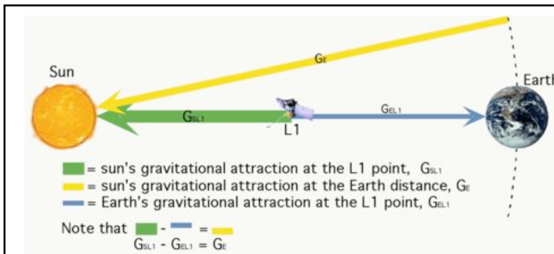
- A small but heavy object – like a ball or rectangular piece of metal
- Rubber bands with varying thicknesses. The tricky part is to find a way to securely attach one end of each of two different rubber bands to the ball or piece of metal
- A spring scale
- A variety of objects of varying mass
- Overhead projector.

Background Information:

A number of satellites have been launched into space to monitor space weather. When they are located in a position of space distant to the planets, they are able to observe materials ejected from the sun as there is nothing in the way to stop the ejecta. If a place can be located where the satellites escape Earth's gravitational force, the satellites essentially become orbiters of the Sun, the largest source of gravity in our system. But where is this point located?

If a spacecraft is placed between the Earth and the Sun, the opposing pull of the Earth reduces the effective pull of the Sun, allowing the spacecraft to orbit the Sun more slowly. If the distance is properly chosen, the orbital motion will match that of Earth, allowing the two to stay together throughout the Earth's annual journey around the Sun.

There is a point in space where the gravitation pulls of the earth and the Sun exactly balance. It is a good place to send satellites because once there, it takes little to no energy to keep them there. The point where this happens is the L1 Lagrangian point (after Joseph Lagrange, the Italian-French mathematician who pointed it out). It is about 4 times more distant than the Moon, at about 1/100 (1%) of the distance of the Sun. The L1 point provides a very useful position for monitoring the solar wind before it reaches Earth and for other purposes. Currently two spacecraft are stationed near L1-- ACE, studying "anomalous cosmic rays" and also observing the solar wind, and SOHO, which observes the sun.



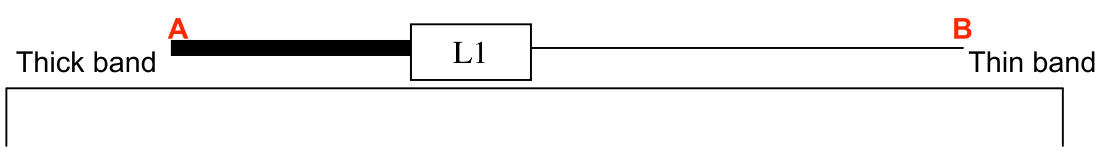
Demonstration: The point of this demonstration is to show that the gravitational forces of the Sun and the Earth determine where the L1 point is located.

Have students observe as you weigh a number of objects. Have them record the weight of each object. Ask the students to explain how the force or pull exerted by each object stretches the spring proportionally. Have the students check out that the pull is directly proportional to the amount of stretch.

Have the students attach a rubber band to a ball or piece of metal (students must be careful as the ball or metal can become projectiles). Have the students exert an opposing force by pulling on the rubber band while holding the ball or metal. How does the students' effort in holding the ball or metal change as greater forces are exerted on the rubber band? Have students record their observations and make conclusions to the amount of force placed on the ball by the amount of stretch on the rubber band. Have the students repeat the process with varying thicknesses of rubber bands. Have students record their conclusions on the board.

Now ask the students how they might model the pulls of the Earth and the Sun on an object? After a few guesses, you want the class to figure out or recall that the gravitational force exerted on an object relates both to the size (mass) of the objects and the distance between the objects. Students must develop an understanding of the fact that the pull of the Sun is much greater than the Earths and to compensate for the fixed gravitational forces, the distance between objects is the factor that can be adjusted to obtain balanced forces. Remind students that gravitational force, decreases with greater distance. Ask students if they would expect L1 to be located nearer to Earth or the Sun? Why?

Take a piece of metal and attach a thick rubber band to one side and a thin rubber band to the other side. Place on an overhead projector. Turn on the light. Slightly pull in opposing directions. Have students record their observations (Which direction does the object move? How much does it move?) Now pull to different degrees on the object. Have students record their observations. How can they explain what they observe.



When you stretch the rubber bands and hold for a short time, the system will settle down as pictured with the object staying at one position – our L1. Establish that when the system is at rest, that the pulls exerted by the two rubber bands must be equal (forces at equilibrium), otherwise the system would continue to move.

Now for some counter intuitive thinking and questioning! Many may be surprised at this point because they expected the thin rubber band to represent the Earth's gravitational force as it exerts less force and to have L1 closer [which is correct]. Since L1 is relatively much closer to point A, the force exerted by the thick rubber band must represent the Earth's gravitational force, as objects at L1 are closer to the Earth!

Have the students' debate that when an object is at a distance much closer to the Earth than the Sun, than the gravitational pull of the Earth must be proportionally stronger than the Sun's as represented by the thick rubber band and the Sun's greater distance produces a weaker "pull", thus the thin rubber band must be stretched more to equalize the force exerted by the Earth.